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BOMEX Flight Tracks Reconstructed From Near-Simultaneous High-Level Cloud Photography by Two Aircraft

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ABSTRACT

Near-simultaneous high-level photography of clouds by two aircraft during the Barbados Oceanographic and Meteorological Experiment (BOMEX) gives some clues to the precision of navigation on this type of mission. Photographs were taken from 50,000 and 60,000 ft., respectively, on two days during BOMEX Period III. On one of the days, the assigned flight track separation of 35 n. mi. is roughly verified, but on the other day the actual separation was found to be less. Examples of the dual photography are shown.

INTRODUCTION

One objective in the analysis of BOMEX data has been to refine initial calibrations of instrument systems and initial reported positions of ships and aircraft used during the 1969 experiment. In the case of high-level cloud photography missions, the flight tracks for all these missions have been reconstructed by combining navigator's notes with internal evidence drawn from the photographs (Myers, 1970, 1971a, 1971b, 1971c). Such evidence includes the apparent motion of the cloud from one photograph to the next, the bearing of an identifiable cloud as the viewing aircraft turned, and the bearing and distance of sun glint on the sea surface. The methods of analysis are described in the references cited above, with a particularly detailed discussion being contained in BOMEX Period III High-Level Cloud Photography Atlas (Myers, 1971a).

On two days during BOMEX, June 21 and July 2, 1969, near-simultaneous missions were flown by two RB-57F aircraft at 50,000 and 60,000 ft. on parallel tracks with an assigned separation of 35 n. mi. In-flight coordination of the positions of the two aircraft was not necessary for these missions - in contrast with some of the BOMEX low-level wind measurement flights, which required close coordination between the relative positions of two aircraft flying in formation on several headings. From the simultaneous photographs of the same clouds obtained fortuitously by two aircraft on the high-level photography missions, it has been possible, nevertheless, to deduce the approximate flight track separation. The most clear-cut examples of these cloud comparisons are presented here, less as evidence of individual flight track reconstructions than as clues to the precision of the RB-57F aircraft navigation, which was, necessarily, based largely on dead reckoning.

During the two simultaneous 50,000-ft. and 60,000-ft. aircraft missions on June 21 and July 2, the assigned track for the 60,000-ft. flight was along the south, east, and north edges of the BOMEX square, while the 50,000-ft. flight plan called for a path parallel to these three sides of the square but 35 n. mi. inside it. These tracks are shown in figure 1.

The cloud photographs reproduced here are black and white 50-percent reductions of the original color transparencies. The photographs were taken by a camera pointing vertically down from the aircraft. The projection of the flight path on the sea surface in each photograph is a straight line through the center of the picture from bottom to top. The left horizon is at the left and the right horizon at the right. The scan from horizon to horizon is obtained by a rotating prismatic mirror within the camera assembly.

A special grid needed to interpret distances on these photographs is shown in figure 2, where distances are indicated in percent of flight altitude above the object viewed. This grid was used in interpreting the distance and location of cloud positions.

JUNE 21, 1969

About halfway along the south leg of the flight, from above an area of extensive overcast (confirmed by satellite pictures), both aircraft entered a clear area with only trade cumuli evident. A large V in the edge of the overcast cloud shield discernable in both series of photographs is thought to be the same cloud feature though the identification is not absolute (see fig. 3). The trade cumuli viewed through this V-notch in the two photographs, however, are not the same. The upper clouds obscured different portions of the sea surface from the two viewing points.

A cumulus cloud line of readily identifiable shape found 8 n. mi. to the left of the 50,000-ft. flight track (upper photograph, fig. 4) toward the end of the south leg was also seen 13 to 15 min. earlier farther to the left by the aircraft flying at 60,000 ft. (lower two photographs, fig. 4).

At the end of the south leg, both aircraft went into maneuvers to collect air samples near the southeast corner of the BOMEX square. For the lower aircraft, this included a descent from 50,000 to 40,000 ft. and return to 50,000 ft. in order to secure air samples at both levels. Soon after starting northward on the east flight leg, both planes photographed the same trade cumulus pattern, as shown in figure 5. (The cloud pattern in the upper panel of the figure is foreshortened in the lower panel by the perspective from a more distant viewing point.) On the basis of these pictures, the aircraft are estimated to have been flying on tracks 20 n. mi. apart. The wind drift of the clouds was taken into account in making this estimate, though the drift was rather trivial, with only a 5-min. time difference between photographs.

Halfway up the east leg, both aircraft overflew a positively identified cloud feature that showed the tracks were tending to converge. From figure 6 it is apparent that the clouds are the same. By taking bearings on the clouds closest to the flight tracks we concluded that the flight paths then were about 8 n. mi. apart.

The aircraft at 60,000 ft. ran out of film on the north leg of the flight, and no photographs could be taken.

On the basis of these cloud comparisons, and some other less definite ones not described here, we determined that the track for the 50,000-ft. flight should be shifted from its flight plan location to a more probable one closer to the 60,000-ft. track, as indicated in figure 7. We applied the entire adjustment to the 50,000-ft. track, rather than adopting compromise locations for both tracks, because the navigator for the 50,000-ft. flight reported some compass difficulties in his flight notes.

JULY 2, 1969

Near the beginning of the south flight leg on July 2, 1969, the aircraft at 50,000 ft. flew over a cloud pattern at 1433 GCT that might be described as a ragged circle (upper panel, fig. 8). We believe that the same cloud feature was photographed from 60,000 ft. from a vantage point farther to the south 8 min. later (lower panel, fig. 8). On the basis of this comparison, we concluded that the two aircraft were close to their planned separation of 35 n. mi.

Over the remainder of the south and east legs, both aircraft were flying above solid cloud decks without identifiable features, but over the north leg they broke out in the clear with only trade cumulus below. The aircraft at 60,000 ft. photographed an interesting line separating trade cumulus in distinct lines from cumulus in chaotic patterns, almost directly beneath the airplane. This is best viewed in a composite of many photographs published in the atlas referred to above and is not reproduced here. The aircraft at 50,000 ft. on a planned track 35 n. mi. farther to the south possibly photographed this feature near the horizon, but it cannot be identified with certainty.

CONCLUDING REMARKS

By comparing the near-simultaneous cloud photographs taken on 2 days during BOMEX by aircraft on parallel tracks with an intended horizontal separation of 35 n. mi., we can conclude the following:

(a) On one of the two days, June 21, the aircraft track separation decreased to as little as 8 n. mi., a deviation from the nominal separation that was attributable to reported aircraft compass difficulties.

(b) On the other day, July 2, no evidence was found of deviation from the nominal track separation of 35 n. mi.

(c) These comparisons are evidence that, in general, the navigation of the RB-57F aircraft, which was dependent largely on dead reckoning and on radio fixes on distant stations that were not ideally located, was successful and that track errors generally did not exceed a few tens of miles.

(d) In scientific measurement programs, such as BOMEX, where location of ships and aircraft relative to each other is important for proper amalgamation of discrete observations, the most up-to-date technological means should be sought for constant recording of exact position of each observation platform.

ACKNOWLEDGMENT

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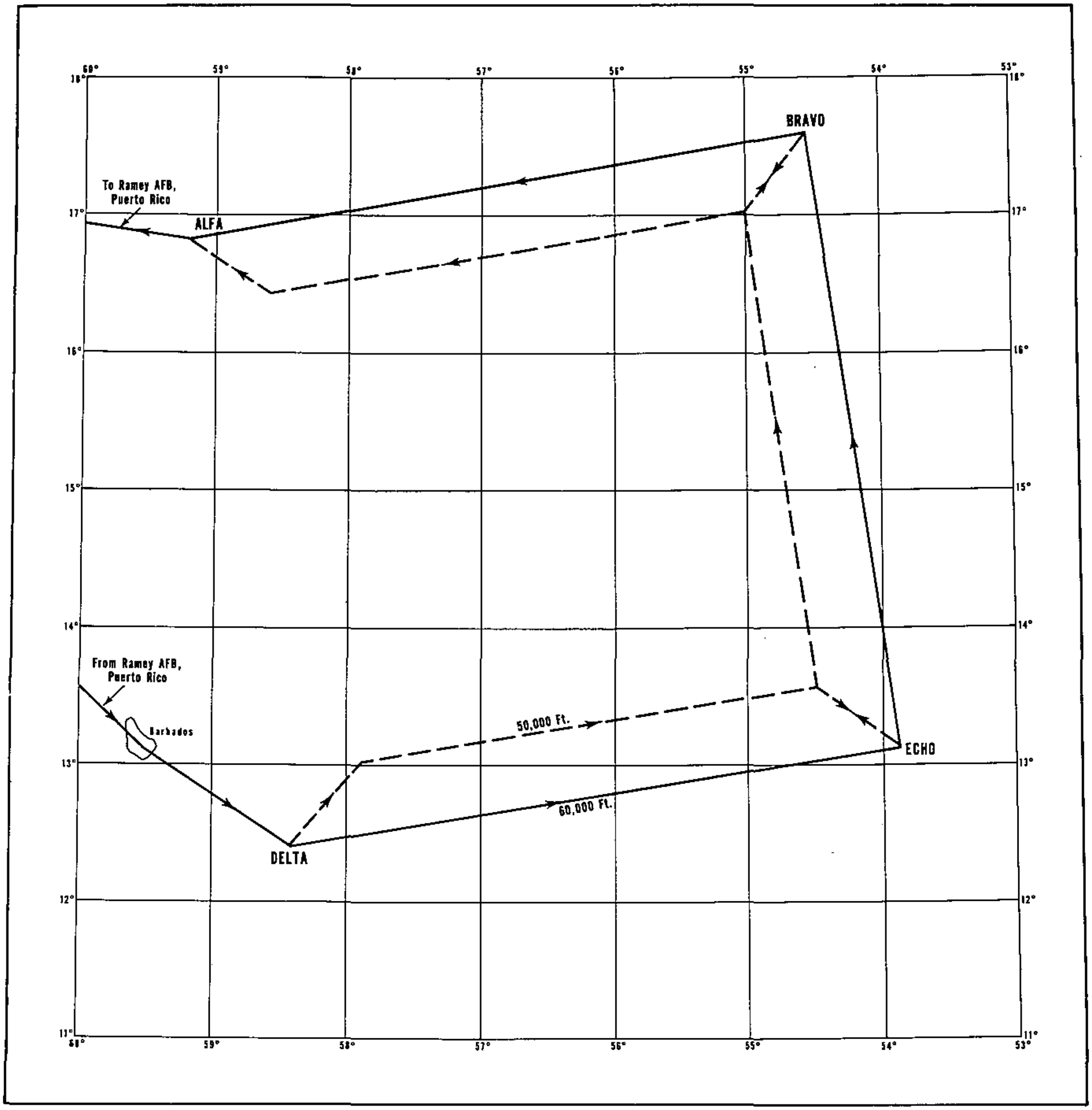


Figure 1.--Tracks as indicated in flight plan for high-level cloud photography from 50,000 and 60,000 ft., BOMEX Period III.

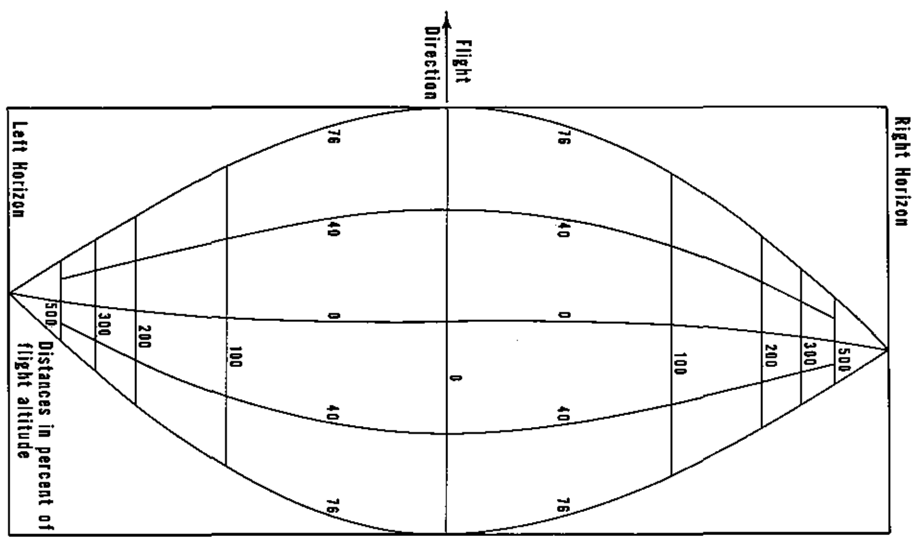


Figure 2.--Overlay grid for panoramic cloud photographs.

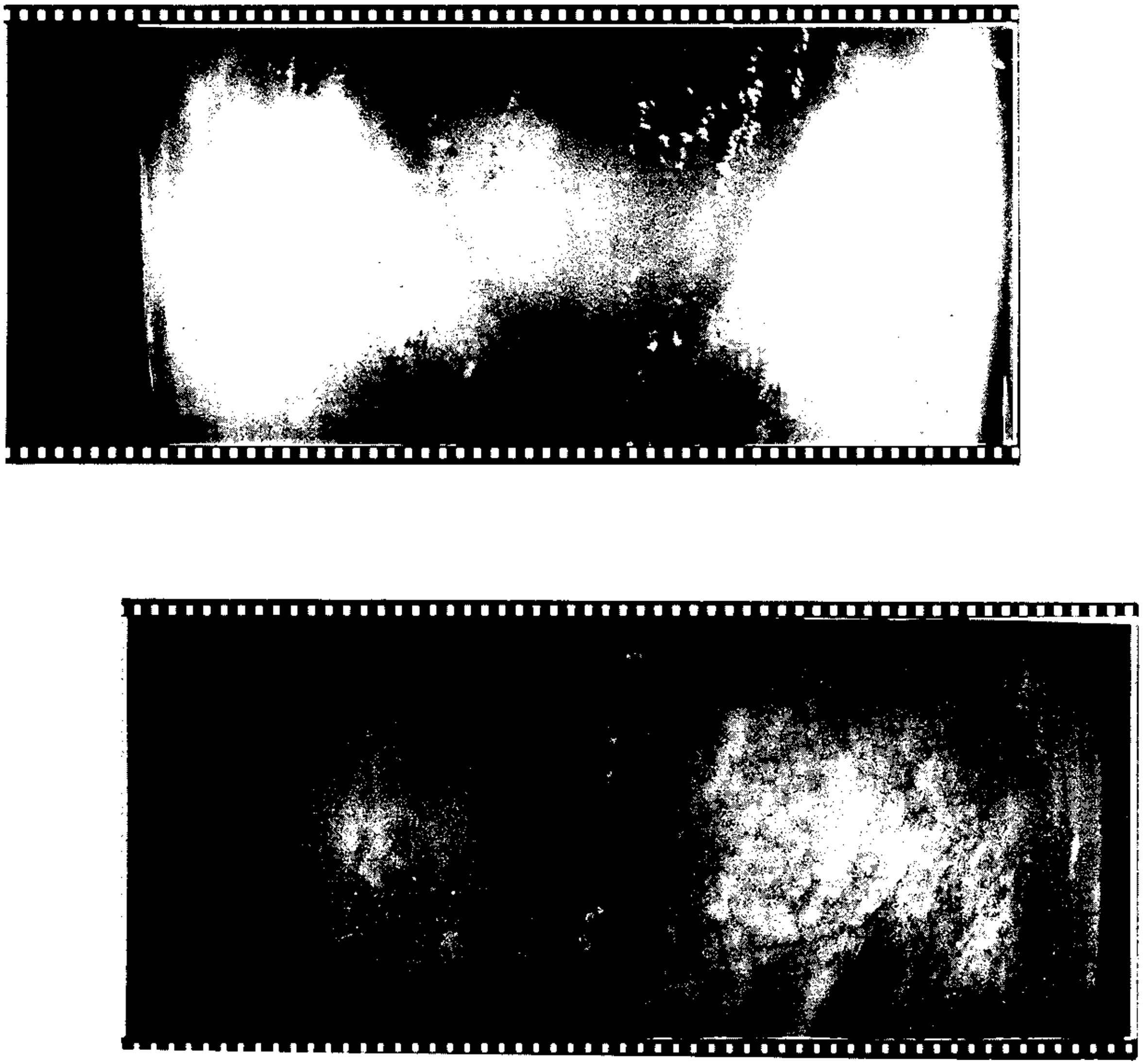
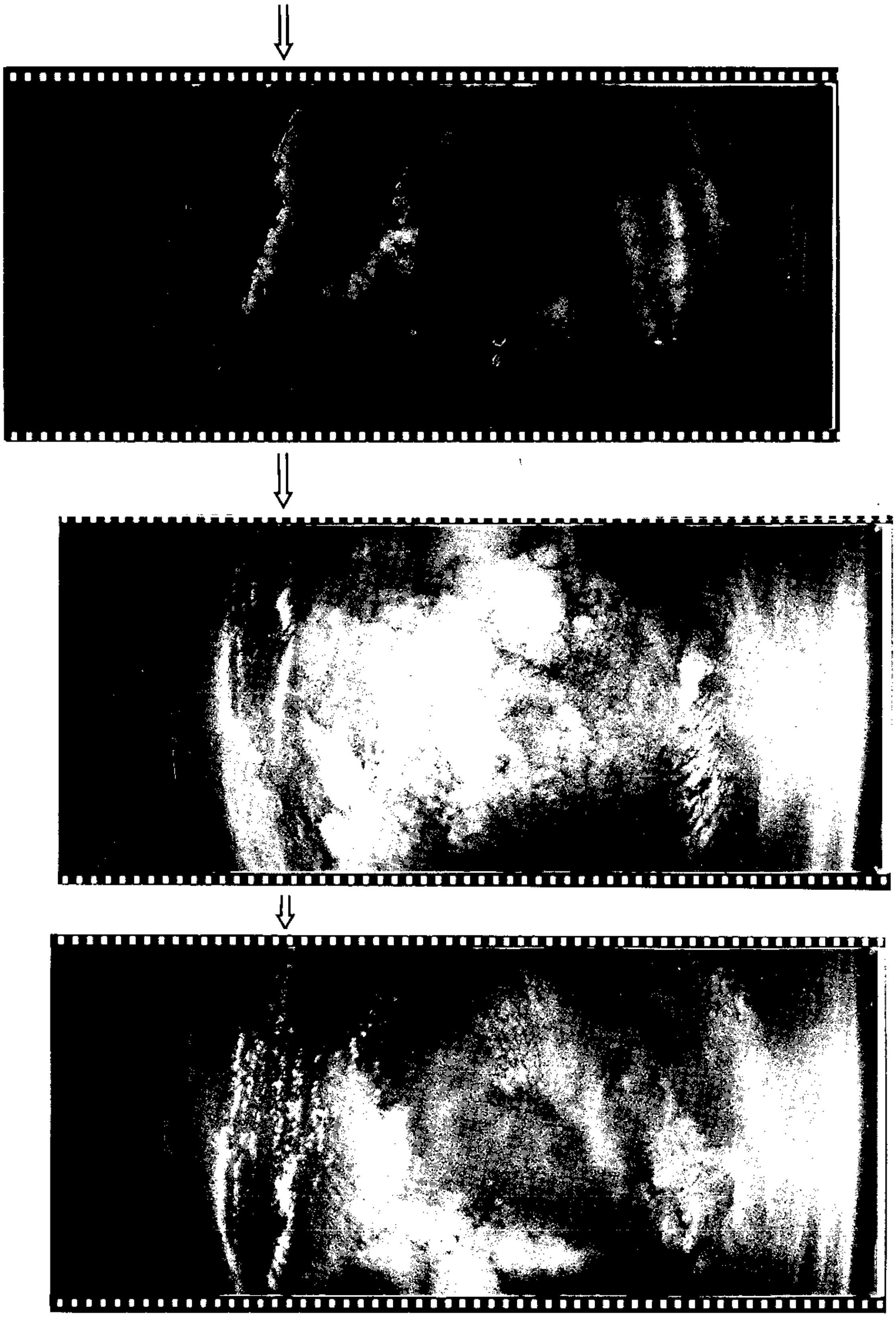
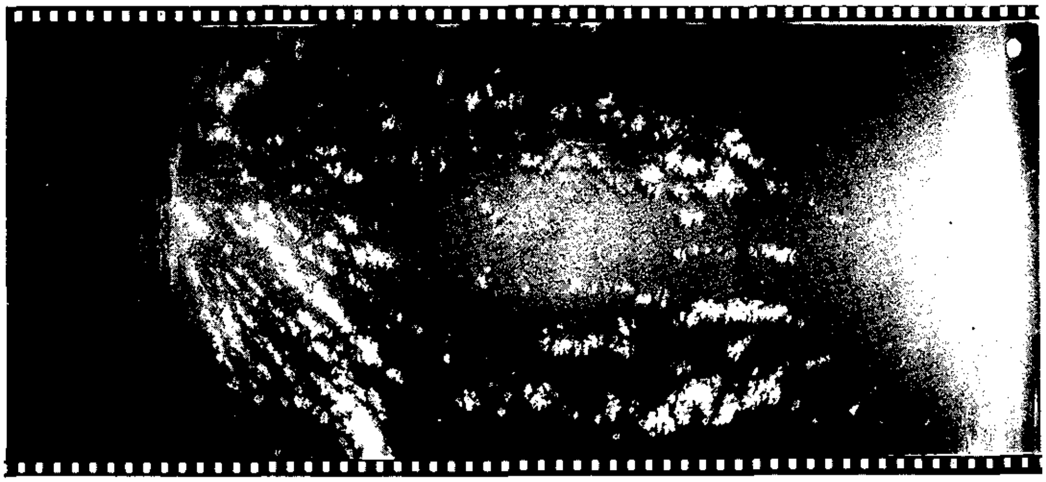


Figure 3.--Photography of V-opening in clouds at 12.9°N 56.0°W, June 21, 1969, from two aircraft. Upper photo from 50,000 ft. at 1452 GCT. Lower photo from 60,000 ft. at 1436 GCT. Aircraft heading 80° (toward top of pictures.) Separation of aircraft tracks estimated at 13 n. mi.

Figure 4.--Photography of cumulus cloud line at 13.3°N 54.8°W, June 21, 1969, from two aircraft. Upper photo from 50,000 ft. at 1503 GCT from approximately 8 n. mi. to the right of cloud line. Lower two photos from 60,000 ft. at 1448 GCT and 1450 GCT from approximately 17 n. mi. to the right of cloud line. Aircraft heading 80° (toward top of pictures). Allowing for wind drift of clouds, separation of aircraft tracks estimated at 11 n. mi.





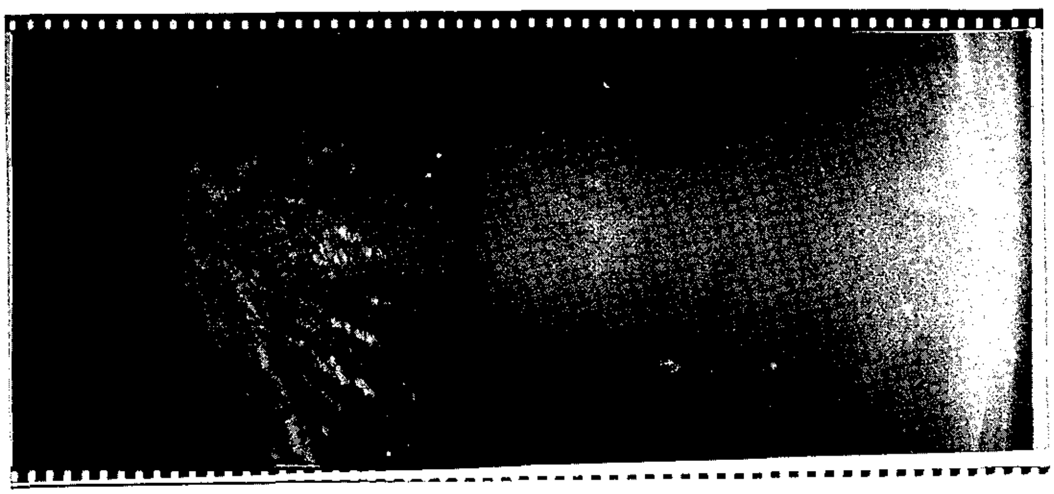


Figure 5.--Simultaneous photography of cumulus clouds at 13.4°N 54.1°W, June 21, 1969, from two aircraft. Upper photo from 50,000 ft. at 1523 GCT. Lower photo from 60,000 ft. at 1518 GCT. Heading of aircraft 350° (toward top of pictures). Track separation estimated at 21 n. mi. Many individual clouds can be identified in both pictures.

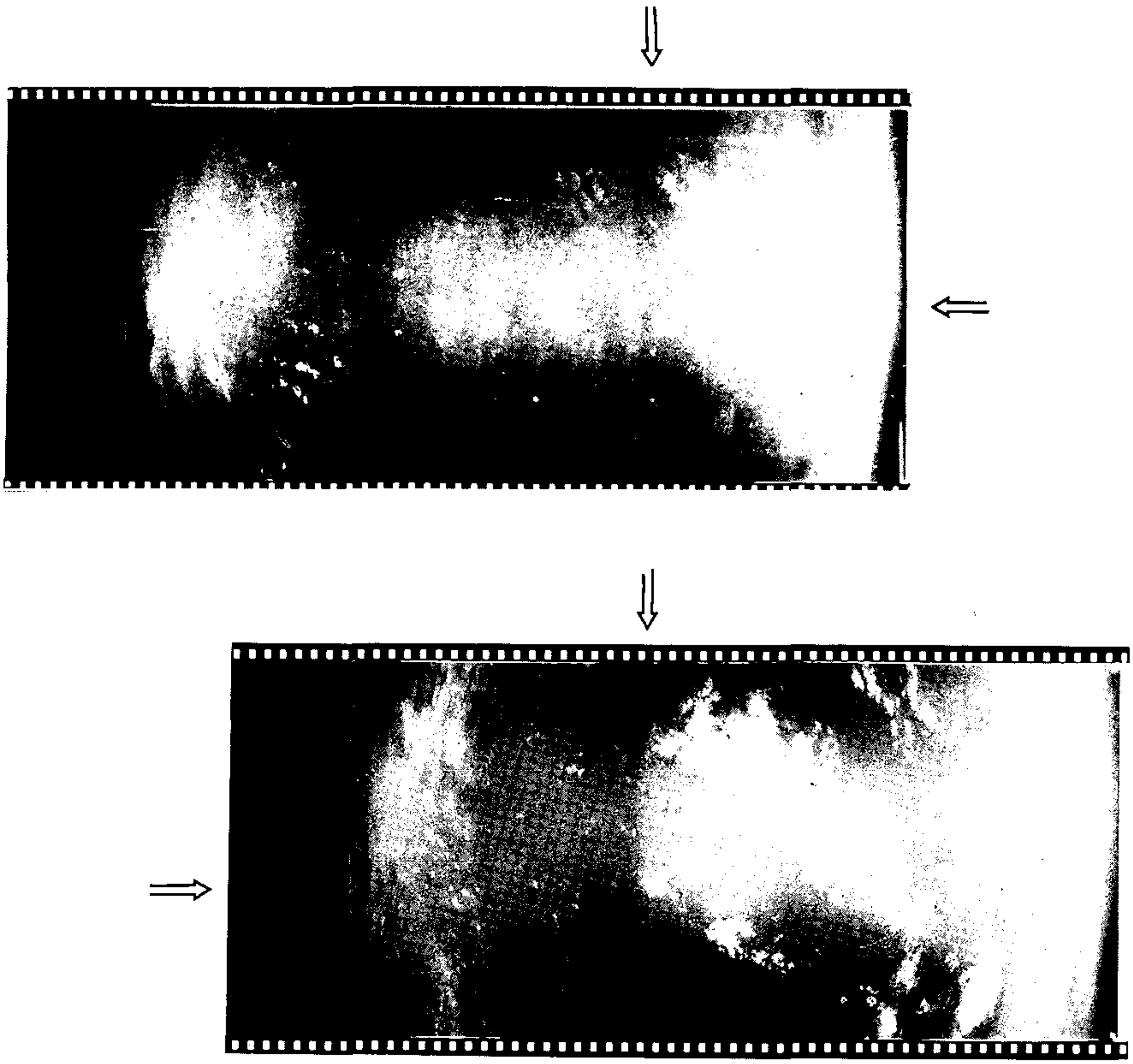


Figure 6.--Simultaneous photography of clouds at 15.4°N 54.3°W, June 21, 1969, from two aircraft. Upper photo from 50,000 ft. at 1542 GCT 6 n. mi. to the left of cloud indicated by arrows. Lower photo from 60,000 ft. at 1534 GCT 2.5 n. mi. to the right of reference cloud. Aircraft heading 350° (toward top of pictures).

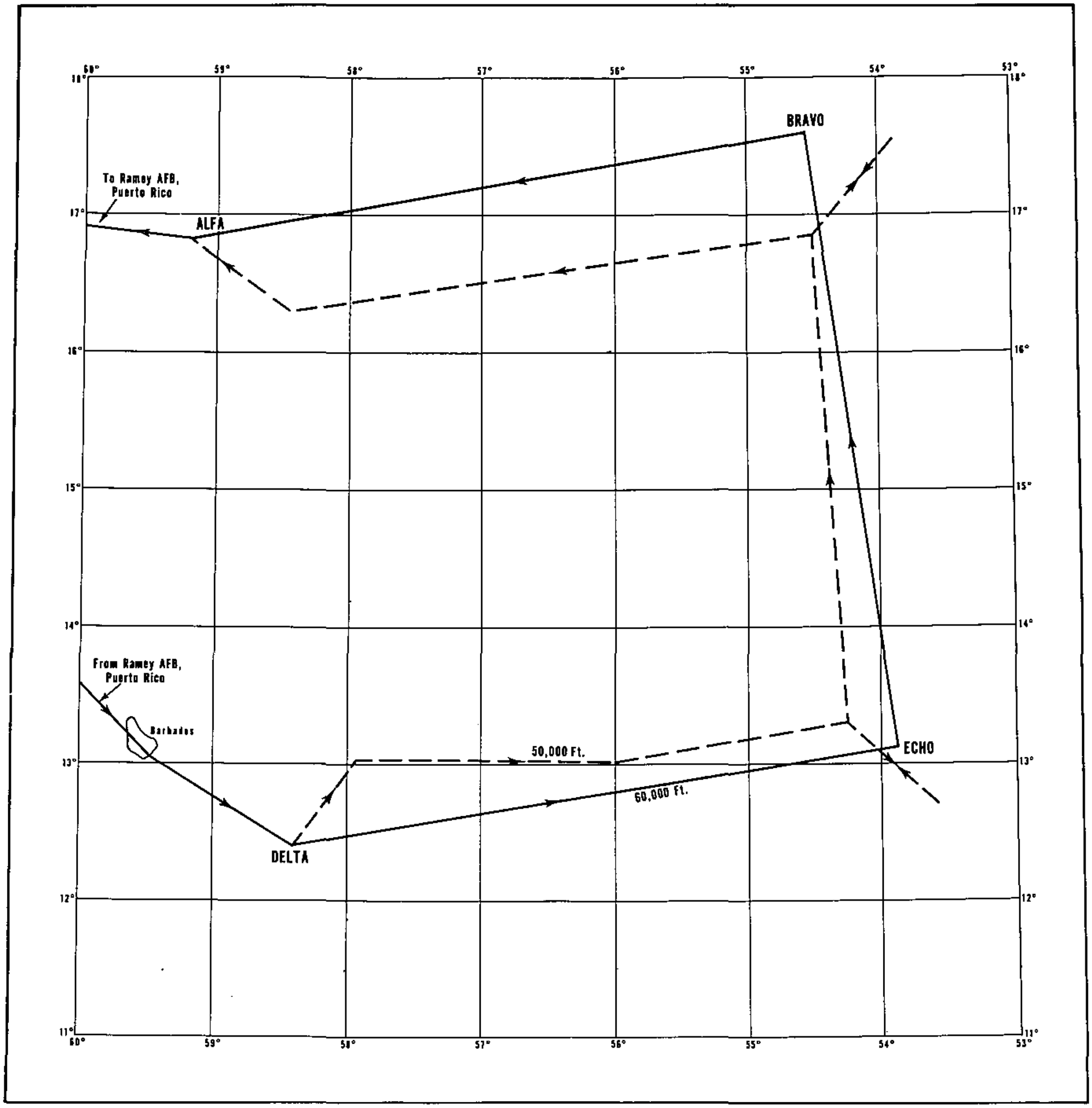


Figure 7.--Estimated actual RB-57F flight tracks at 50,000 and 60,000 ft., June 21, 1969.

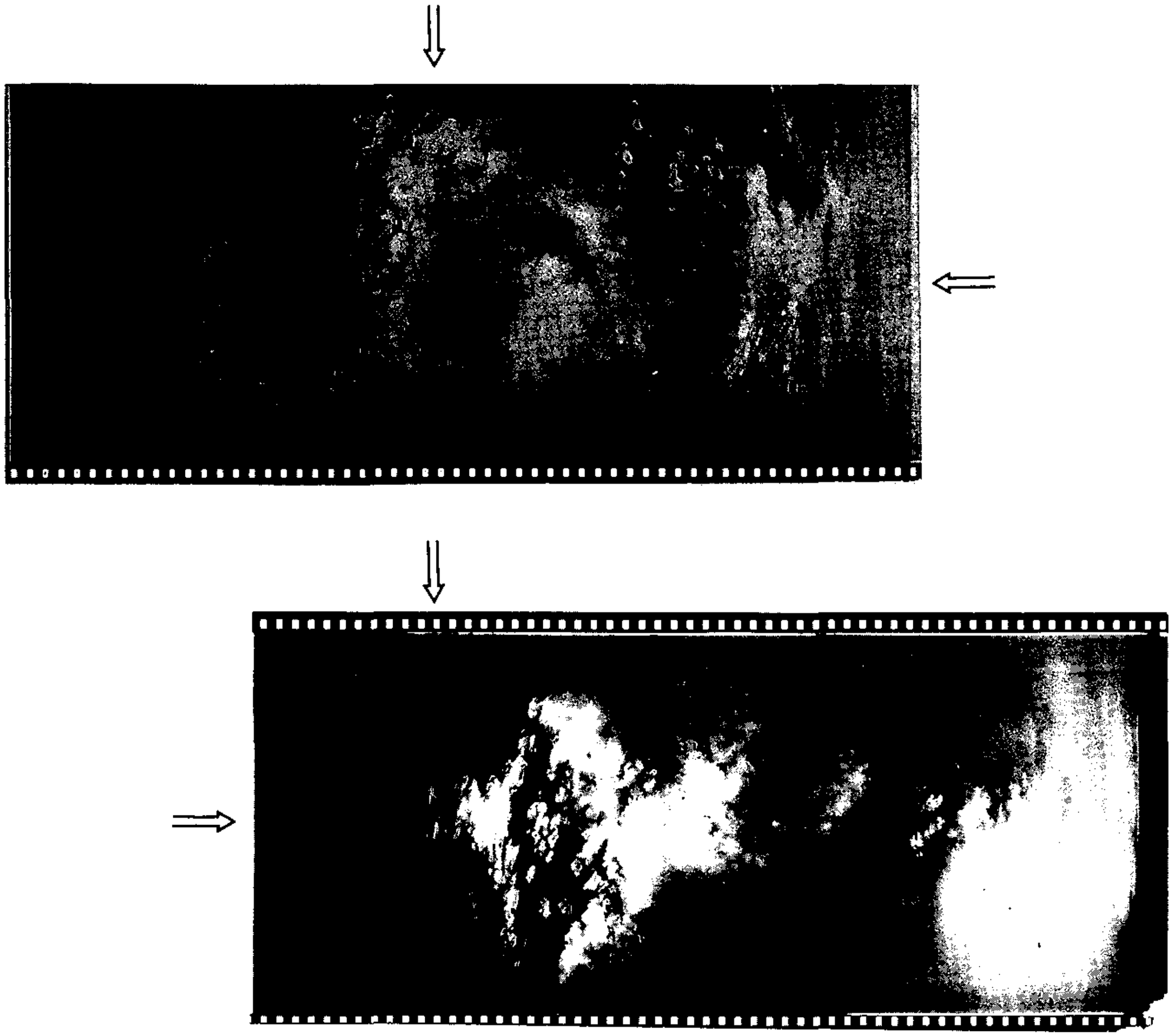


Figure 8.--Simultaneous photography of cloud ring at 13.1°N 57.6°W, July 2, 1969, from two aircraft. Arrows point to center of cloud ring. Upper photo from 50,000 ft. at 1433 GCT from above cloud. Lower photo from 60,000 ft. at 1441 GCT from 38 n. mi. to the right of cloud feature. Aircraft heading 80° (toward top of pictures).